**A THEORETICAL STUDY OF $SO_2$ TRANSPORT BY EXPLOSIVE VOLCANISM ON VENUS;** ***Lori S. Glaze**, Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109*

It has been proposed that explosive volcanism may occur on Venus, despite high atmospheric pressure and extreme surface temperatures, in an effort to explain the variability of $S0_2$ concentrations observed at the Venus cloud tops (40 mbar or -70 km above mean planetary radius [ampr]) [1,2]. In support of this suggestion, recent geochemical studies of weathering processes on the Venusian surface indicate that ~1 $km^3/yr$ of magma would have to be erupted in order to supply $SO_2$ at a sufficient rate to remain in equilibrium with surface scavenging [3]. Even higher rates of volcanism are suggested by geophysical studies [4]. This study shows that volcanoes can erupt explosively under conditions found on the surface of Venus but that the buoyant plumes generated by these eruptions are very sensitive to the ambient atmospheric stability. Earlier theoretical studies of explosive volcanism have presumed simplistic atmospheric temperature and pressure profiles; however, there are several indications that the Venusian atmosphere is mom stable than previously assumed. Extremely stable atmospheres are shown to have the most potential for producing the highest plumes. It, may also be possible that tropospheric circulation is partially responsible for the transport of volcanic material, in which case, explosive volcanic eruptions would not be required to generate extremely high plumes in order to explain high concentrations of volcanic $S0_2$ at the Venusian cloud tops.

*Ambient Sensitivities*

Theoretical studies of explosive volcanism on Venus conducted in recent years have used a simple, globally averaged temperature and pressure model derived from the four Pioneer Venus probes sent into the Venusian atmosphere [6]. These studies concluded that it is unlikely that explosive volcanism on Venus could produce anything more than very small buoyant plumes. The dynamics of convective columns, however, are sensitive to atmospheric pressure and temperature profiles. Recent work [5,6] has shown that the final heights of volcanic plumes are very sensitive to the atmospheric lapse rate, and hence the degree of atmospheric stability. There are two problems with the simplistic atmospheric temperature model used in the past: there is significant uncertainty near the surface and latitudinal variations must be considered.

*Near. **Surface Profile:*** Very little is known about the temperature structure near the surface of Venus because none of the four Pioneer Venus probes returned temperature measurements below 12 km altitude (ampr). Due to this lack of data temperatures near the surface have been extrapolated from higher altitude data. Recent work by D. Crisp and V. Meadows (pers. comm.), however, has shown that the near-surface lapse rate may be steeper than previously assumed, resulting in an atmosphere that is much more stable, thus increasing the rise potential of buoyant plumes.

*Latitudinal Variation:* Existing data [7] show that there is a significant latitudinal variation in the temperature gradient between 40 and 60 km (ampr). Seiff [7] reported that atmospheric temperatures in this region may drop much more sharply at higher latitudes (above 60°) than at mid and equatorial latitudes. This steeper lapse rate is indicated by both the 59” N Pioneer Venus probe and the radio occultation data from the Pioneer Venus Orbiter. This again indicates a more stable regime and, therefore, is very important for volcanic plume rise and, hence, $SO_2$ transport. As an example, volcanoes erupting explosively with identical initial conditions are most likely to produce the highest plumes in the regions above 60", Furthermore, some of the highest volcanoes on Venus are located in the northern latitudes, adding additional rise potential through the initial height as well as the difference in initial ambient pressure (50 bars at 8-9 km ampr as opposed to 90 bars at O ampr), again adding to the rise potential of an explosive volcanic plume. A volcano in the Maxwell Montes region, therefore, has a strong potential for producing a comparatively high plume. The higher a plume is able to rise in the atmosphere, the easier it is to explain the accumulation of $SO_2$ at the top of the troposphere.

*Theoretical Calculations*

The theoretical model used in this study to describe the rise of buoyant plumes is based on the Glaze and Baloga [5] buoyant plume model that assumes a system of ordinary differential equations describing the conservation of volume, mass, momentum and thermal energy as first describe by Morton *et al. [8].* The ambient parameters have been modified for the conditions found on Venus and the plume composition has been assumed to be the same as the ambient atmosphere. For test purposes, I have assumed an initial plume radius of 300 m (which is within the reasonable range given current knowledge) and a vent height of 10 km (requiring the volcano to be located at one of the highest points on the planet's surface). I have then varied the initial velocity independently between 300 and 900 m S-l. The initial velocity is integrally tied to the gas mass fraction, but the velocity has been allowed to vary for illustrative purposes. The first initial velocity of 300 m S-l is a realistic value for the chosen gas mass fraction of 0.03 [9]. The model plumes have then been released into several atmospheric regimes, including the simplistic, globally averaged atmosphere, a northern latitude profile [7] and a more stable near surface profile. The results for the globally averaged model indicate that even the physically implausible 900 m S-l initial velocity is incapable of maintaining a plume at 40 km altitude. This is nowhere near high enough for a direct injection of volcanic material into the cloud layer. The other atmospheric profiles show much more promise for direct injection.

It may not be necessary, however, to directly inject volcanic material into the top of the cloud layer. It is possible that atmospheric circulation may be at least partially responsible for transporting the volcanic $SO_2$. In this instance, explosive eruptions may only be required to generate plumes extending a few kilometers above the vent. Future research will include a study of the time and spatial scales for circulation in the Venus troposphere.

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